To: Ms. Kristina Ronneberg, Office of the Undersecretary of Energy

Submitted Through: WorkforceRFI@hq.doe.gov

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Subject: Response to Request for Information DE-FOA-0000402 Concerning Energy Education and Workforce Development

We applaud the DOE's engagement in education and workforce development to help advance the United States' transition toward a sustainable, low-carbon energy future. As the Energy Education and Workforce Development RFI demonstrates, crafting an outstanding national system for energy education is a complex task involving massive amounts of information, a vast institutional infrastructure, myriad pedagogical options, and diverse communities of learners with a variety of educational styles, starting points, and needs.

This submission focuses on energy education at the undergraduate level. MIT's flagship energy education effort is the undergraduate Energy Studies Minor, launched in 2009 as the first academic program at MIT specifically designed to integrate student learning across the domains of science, engineering, and social science. We believe that the fundamentally multidisciplinary stance toward energy education that is embodied in the Minor is crucial to the Department's efforts to prepare a workforce capable of the short- and long-term adaptations that will be necessary over the next several decades in response to evolutions in the technological, governance, and economic dimensions of the energy landscape. Individual members of the energy workforce – from the boardroom to the lab bench to the shoproom floor – will likely have to navigate significant individual and organizational transitions as the energy landscape shifts. The foundation of their adaptive capability is a robust appreciation of the complexity of our energy systems, and undergraduate education is a critical stage at which to develop multidisciplinary fluency in energy.

This submission provides a brief description of MIT's approach to multidisciplinary energy education as a potential model for other undergraduate programs and offers some guiding principles for energy education based on this experience. We include MIT President Susan Hockfield's August 19, 2009 letter to Under Secretary Kristina Johnson on energy education priorities as an attachment to this submission.

MIT's Energy Studies Minor Curriculum

The MIT Energy Studies Minor is comprised of a core curriculum and an elective requirement (web.mit.edu/mitei/education/minor.html). The core curriculum of the Energy Studies Minor at MIT engages students in energy fundamentals in the three basic domains of science, engineering, and social science.

The *Energy Science Foundations* requirement covers fundamental laws and principles that govern energy sources, conversion, and uses. This requirement equips students with a scientific understanding of energy systems according to the following guidelines:

> We expect that any student graduating with the energy minor should have been exposed to the basic scientific principles underlying all (or at least most) components of the energy landscape, from energy sources to end uses, including energy conversions, storage, and impact on climate. The student should have some understanding of the physical laws governing and limiting energy processes, as well as an ability to relate the theoretical laws to practical energy systems, and a global picture of how different systems fit together. Any student granted the minor should have had sufficient exposure to the science of energy that they could, for example, work as a staff member assisting a politician on energy issues, and would have the background needed to place any energy issue into a scientific context and have some initial knowledge to use as a starting point for investigating any particular question.

The *Social Science Foundations of Energy* requirement addresses social scientific perspectives and tools that explain human behavior in the energy context. Students are introduced to, explore, and compare several disciplinary frameworks (ie economics, management, political science) in the context of real-world energy decision-making.

The *Energy Technology/Engineering in Context* requirement trains students to apply laws and principles to specific energy contexts. These classes may provide students with a broad view of technologies for energy generation, distribution, and use (ie fossil fuels, renewables, electric grid, batteries); delve into the range of technologies for energy management within a specific use environment (ie buildings, transportation); or develop specific analytic skills applicable to a wide array of energy technologies (ie conversion, efficiency).

Through the *Energy Elective* requirement, students customize their program of energy study. They may choose to more deeply explore energy applications of their major area of study, to further pursue their interest in one of the core curriculum domains of the minor, or to sample multiple areas of interest. Electives are offered in areas such as energy policy, economics and business management; a range of technologies including solar, nuclear, and buildings; climate issues; and developing world applications.

It is important to emphasize that crafting an innovative academic program is a major undertaking and as such requires significant and sustained faculty effort and financial and human resources. The Energy Studies Minor at MIT took shape over several years. Student and faculty interest in an undergraduate energy minor emerged in 2005 and gained momentum with the deliberations of the Energy Research Council in 2006 and the formation of the MIT Energy Initiative (MITEI) in 2007. MITEI's Energy Education Task Force, a standing faculty committee including representatives from all five Schools (Architecture and Planning; Engineering; Humanities, Arts, and Social Sciences; Management; and Science), devoted over a year to the deliberations that resulted in the intellectual framework of the Minor. Another year of discussion and negotiation at the departmental and institutional levels was necessary to generate new multidisciplinary structures for governance and advising and to gain approval of the full faculty to launch the Minor program.

MIT's experience highlights the crucial importance of a dedicated, multi-departmental core group of faculty in both the intellectual and community-building aspects of a major experiment in multidisciplinary education. Additional key factors in the process included the leadership of President Susan Hockfield and her senior administration; major gifts from alumni to support the development of critical new classes and the adaptation of several existing classes; and the availability of dedicated professional staff in the MIT Energy Initiative. Many of the lessons learned through this process may be transferrable to other educational institutions, and we would be happy to provide more detailed information regarding the activities and resources with which MIT established the Energy Studies Minor if desired.

Some Guiding Principles for Energy Education

1) ***Energy education must be multidisciplinary.*** In her August 2009 letter to DOE Under Secretary Kristina Johnson, MIT President Susan Hockfield wrote that "an energy education that meets the country's critical need for 'energy preparedness' must necessarily be multidisciplinary." Effective and adaptable solutions to energy challenges require that workforce members are not locked into narrow ways of thinking. It is essential that members of the energy workforce have the capacity to appreciate, absorb, and work effectively with information, individuals and organizations from outside of their own area of expertise.

2) ***Multidisciplinary education is not anti-disciplinary education.*** Bringing multiple disciplines together means energy education must include the rigor of deep understanding of the tools and ways of thinking of a core discipline. This is and will continue to be the bedrock of an MIT education and is the fundamental reason that MIT chose to develop a minor rather than a major in energy. Depth of knowledge and specialization are both needed, but are not by themselves sufficient. Members of the nation's energy workforce must appreciate and apply their specialty in the complex and dynamic context of energy systems.

3) ***Multidisciplinary education requires integrative learning.*** The sheer complexity of global energy and climate challenges requires integrating expertise from many disciplines. This is easy to recognize but difficult to systematically operationalize and measure. Many traditional learning environments are not ideally equipped to foster or to evaluate integrative learning. Several pedagogical observations on the challenge of integrative learning for energy arising from experience to-date with MIT's Energy Studies Minor are shared here.

    a. Integrative learning may take place organically. Students who pursue multiple areas of study on different tracks may themselves draw tools and perspectives from one field to apply to problems or questions arising in another, even without being explicitly encouraged to do so. Extracurricular pursuits such as internships and student group projects can serve as particularly fertile ground for making these connections.

    b. However, in the context of energy, integrative learning may be too important to leave to chance. Integrative learning can be fostered at the level of the academic program, the individual course, in a particular class session, and in specific assignments. It can be fostered outside the formal curriculum in research projects, living communities, and through advising. Classes that foster integrative learning can be comparative, project-based, or capstone. Design for integrative learning can have excellent results at all stages of education, from the orientation and introductory work of first-year students through projects and theses required for seniors.

    c. Integrative learning for energy benefits significantly from exposure to and engagement with real world problems and situations. For the most cutting edge technology to help society make progress in addressing energy challenges, its developers should be cognizant of the need to also investigate its economic viability and environmental impacts, and should know how to work with those who have the expertise to seriously address these considerations.

4) ***Multidisciplinary education for energy requires a strong science foundation.*** At MIT, the Energy Studies Minor curriculum relies specifically on the strong grounding in basic sciences that all undergraduates develop via the General Institute Requirements, which include calculus, physics, chemistry and biology. There is no substitute for scientific literacy. Real progress in strengthening primary and secondary education in science and engineering is vital for the development of the nation's energy workforce.

5) ***Emerging best practices in multidisciplinary energy education need broad dissemination*** and discussion among formal and nonformal educators at all levels. Both digital and interactive means should be deployed. MIT's OpenCourseWare (OCW) is one example. A web-based publication of virtually all MIT course content, OCW averages more than one million visitors to content each month and is widely used by students and educators. We are working continuously to publish new energy course materials on OCW, and will launch a special energy portal including video content next year. These materials could serve as a model for other universities and community colleges as they develop energy curricula. The online course approach, potentially available on iPods, cell phones, and e-readers as well as on desktops and laptops, could dramatically increase the impact of energy education programs nationwide by reaching millions of students. OCW and other online resources provide an important forum for educators to find and discuss new ideas and begin to sort out best practices; they should be supplemented with interactive workshops.

In closing, we offer the content and approach of the Energy Studies Minor at MIT as a model for undergraduate energy education that can help develop an outstanding workforce to steer the nation toward an economically and environmentally sustainable energy future. We hope you find this submission useful in your next steps to create and support education and training programs toward that end. Please do not hesitate to contact us directly if we can provide additional information or be of further assistance.

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